

Food Animal Economics

Potential revenue impact of an outbreak of foot-and-mouth disease in the United States

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Objective—To estimate potential revenue impacts of an outbreak of foot-and-mouth disease (FMD) in the United States similar to the outbreak in the United Kingdom during 2001.

Design—Economic analysis successively incorporating quarantine and slaughter of animals, an export ban, and consumer fears about the disease were used to determine the combined impact.

Sample Population—Secondary data for cattle, swine, lambs, poultry, and products of these animals.

Procedure—Data for 1999 were used to calibrate a model for the US agricultural sector. Removal of animals, similar to that observed in the United Kingdom, was introduced, along with a ban on exportation of livestock, red meat, and dairy products and a reduction and shift in consumption of red meat in the United States.

Results—The largest impacts on farm income of an FMD outbreak were from the loss of export markets and reductions in domestic demand arising from consumer fears, not from removal of infected animals. These elements could cause an estimated decrease of \$14 billion (9.5%) in US farm income. Losses in gross revenue for each sector were estimated to be the following: live swine, -34%; pork, -24%; live cattle -17%; beef, -20%; milk, -16%; live lambs and sheep, -14%; lamb and sheep meat, -10%; forage, -15%; and soybean meal, -7%.

Conclusions and Clinical Relevance—Procedures to contain an outbreak of FMD to specific regions and allow maintenance of FMD-free exports and efforts to educate consumers about health risks are critical to mitigating adverse economic impacts of an FMD outbreak. (*J Am Vet Med Assoc* 2002;220:988-992)

The United States has been free of foot-and-mouth disease (FMD) since 1929. However, the 1997 outbreak of FMD in Taiwan and the 2001 outbreak of FMD in the United Kingdom raised concerns about the potential impact should FMD reappear in the United States. McCauley et al¹ reported in 1979 that the impact of an FMD outbreak in the United States would range from \$0.2 billion in losses for an outbreak con-

trolled through eradication and vaccination restricted to specific areas to \$27.6 billion in losses for a worst-case scenario in which there was an endemic outbreak with only voluntary vaccination. In 1999, Ekboir² examined the potential impacts of an FMD outbreak in California and estimated that losses would range from \$8.5 billion to \$13.5 billion. An important finding in that study was that approximately \$6 billion of the total impact was attributable to loss of international markets for export of US livestock products. Finally, we have reported^{3,4} the use of various risk-based types of import barriers for beef trade with countries that have FMD, using estimates of output loss from the study by McCauley et al.¹

The study reported here was conducted to estimate the possible economic consequences of an FMD outbreak in the United States, assuming the outbreak would be similar to the spring 2001 outbreak in the United Kingdom. Estimates were calculated by using a model for the US agricultural sector that included livestock, livestock products, and crops. The outbreak was analyzed in 3 successive components. First, animal inventories and milk production were reduced as a result of the direct impact of the disease on farms. Second, a ban on export sales of all susceptible US livestock and livestock products was added. Finally, consumption of meat and milk in the United States was reduced to account for consumer fears of the disease, even though risk of disease transmission to humans through consumption of red meat and dairy products has not been reported and would have to be considered virtually nonexistent.

Materials and Methods

A simple graphic model was used to illustrate the potential impacts of an FMD outbreak in the United States (Fig 1). For our model, we assumed that the United States is an exporter of a single good (eg, meat). The initial domestic supply and demand prior to the FMD outbreak were determined. The difference between these lines indicated the quantity available for export from the United States for each price or amount of excess supply. The demand of other countries for importation of US meat also was determined.

Prior to the FMD outbreak, the equilibrium price was determined as the point at which the US supply for export equaled the import demands of other countries. The quantity of meat consumed in the United States and the quantity of meat supplied were determined. The quantity of meat exports from the United States was the difference between domestic supply and demand.

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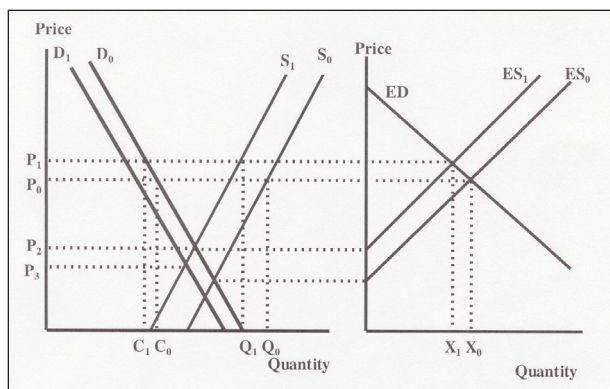


Figure 1—Graphic model used to illustrate the potential economic impacts of an outbreak of foot-and-mouth disease (FMD) in the United States on a single commodity (ie, red meat). The lines labeled S_0 and D_0 identify the initial domestic supply and initial domestic demand, respectively, prior to the FMD outbreak (left panel). The difference between these lines is the quantity available for export from the United States for every price or amount of excess supply (depicted by the line ES_0 ; right panel). The line ED indicates foreign demand for US meat. Prior to the FMD outbreak, the equilibrium price (P_0) is determined at the point where the supply for US export equals the demand for importation by other countries. The quantity of meat consumed in the United States (C_0) and the quantity of meat supplied (Q_0) are indicated. The quantity of US meat exported is the difference between domestic supply and domestic demand (X_0 , determined as $Q_0 - C_0$). After an outbreak of FMD in the United States, 3 components combine to affect markets. First, quarantine and slaughter of livestock reduces the domestic supply of meat, shifting the domestic supply (line S_1). In turn, the US supply for export is reduced (line ES_1). As a result, the price increases to P_1 . Exports decrease to X_1 , domestic consumption decreases to C_1 , and supply available for domestic consumption decreases to Q_1 . Second, when exports are prohibited the equilibrium price, P_2 , is determined at the point at which domestic demand intersects domestic supply. Third, if consumers react adversely to the outbreak, the domestic demand decreases from D_0 to D_1 , yielding equilibrium price P_3 .

We then assumed that there was an outbreak of FMD in the United States. In that scenario, 3 components combined to affect markets.

First, quarantine and slaughter of affected livestock reduced the domestic supply of meat. In turn, the US supply for export was reduced. As a result, the price increased, which decreased the quantity exported as well as the quantity consumed in the United States. Consumers in the United States would have an economic loss because of the higher prices they face. The effect on the aggregate economic welfare of US producers was more complicated. Supply was reduced, but prices were higher. Producers in regions of the United States not affected by the outbreak would have an economic gain by selling animals at higher prices. Producers affected by the outbreak could not sell their animals. Without government compensation, the loss of affected producers was measured by the value of lost sales, because they incurred the cost of feeding, housing, and caring for animals that became infected.

Second, when we added the effect of other countries placing embargoes against importation of US livestock and livestock products because of the FMD outbreak, prices in the United States decreased to the point at which domestic supply equaled domestic demand. Consumers benefited, because the supply of meat formerly destined for international markets remained in the US market, depressing the price. However, producers received lower prices on a smaller quantity of meat.

In addition to the outbreak's impact on domestic supplies and exports, the third component (ie, consumer fears) could affect prices. It is possible that some US consumers

may develop fears about contracting FMD and, thus, may reduce or eliminate their consumption of red meat, which would cause a shift (ie, decrease) in domestic demand. Thus, prices would decrease further, and producers would have even greater losses.

An empirical partial-equilibrium model of the US agricultural sector with 3 market levels was used to quantify the magnitude of the impacts of the aforementioned 3 components. This style of model has been reported elsewhere.^{5,6} Five crops (wheat, coarse grains,⁴ soybeans, rice, and forage) are grown to provide food for humans as well as livestock. Soybeans are crushed for oil and meal. Soybean oil is used in food as well as industrial products, and soybean meal is used to feed livestock. Feeds are used to produce cattle, swine, sheep, and poultry that, in turn, become meat, milk, and eggs. Additional details of the model description and variables were provided (Appendix).

The model determined short-run (1 year) impacts calibrated for 1999 to 2000 data from various USDA reports.⁷⁻⁹ This meant that livestock producers would have differing supply responses. Poultry and egg producers would be able to fully respond to price changes within a 1-year time frame, whereas swine producers would have a more limited ability to respond. Cattle and sheep producers would have almost no ability to adjust livestock numbers in response to price changes within such a short time period. We incorporated US agricultural support programs into the model, including Agricultural Market Transition Act payments, Loan Deficiency Payments, and commodity-specific trade interventions.

Many factors that would determine the extent and magnitude of a US outbreak cannot be forecast. Thus, the FMD outbreak in the United Kingdom in spring 2001 was used as a benchmark for our analysis. As of May 21, 2001, the UK Ministry of Agriculture, Fisheries, and Food¹⁰ reported that 465,000 cattle, 118,000 swine, and 2,418,000 sheep had been slaughtered in an attempt to control the outbreak. Relative to the beginning inventory for 2001, the percentage of each type of livestock that had been removed was as follows: cattle, 4.3%; swine, 1.7%; and sheep, 7.9%. Percentage reductions in livestock were used in our analysis to account for the difference in size between herds in the United States and those in the United Kingdom. Actual reductions (beef cattle, 5%; milk production, 5%; swine production, 2%; lamb and sheep, 9%) were assumed to be slightly larger than the calculated percentage change, because FMD was not fully eliminated by May 21, 2001.^b

Although the UK situation provided a benchmark, it is important to recognize important differences in US agriculture that could affect the spread and magnitude of any FMD outbreak in the United States. Authorities in the United Kingdom have been criticized for being slow to react. Given what happened in the United Kingdom, US authorities are fully alerted and prepared to respond quickly. The UK livestock industry is densely packed with a greater reliance on farms that consist of several species of animals. Sheep, which were the animals most severely affected during the outbreak, are more important in the United Kingdom. At the same time, livestock operations in the United Kingdom are generally smaller than those in the United States.

In our model, all exports of cattle, beef, swine, pork, poultry meat, lambs, lamb meat, sheep, sheep meat, and dairy products were embargoed. Elimination of exports would be consistent with experiences in the United Kingdom, Taiwan, and other nations following FMD outbreaks. It also is consistent with results for the study of Ekboir² in which a substantial share of the estimated impact attributable to an outbreak of FMD in California was caused by a halt in US exports.

The potential response of consumers to an FMD outbreak has been overlooked in other studies. In Europe, there has been considerable adverse consumer response to live-

stock diseases. However, European consumers also face concerns about **bovine spongiform encephalopathy (BSE)**, so disentangling the effects of FMD and BSE is difficult. During the FMD outbreak in the United Kingdom, US consumers indicated confusion about the differences between FMD and BSE as well as a weak understanding of the human health risks attributable to FMD. Consequently, the impacts from an adverse consumer reaction were estimated. The extent of consumer fears regarding FMD is unknown. For the analysis reported here, we assumed that 90% of consumers would be unaffected and that 10% of consumers would stop eating red meat and dairy products but would consume more poultry meat. Thus, there was a shift in the composition of US food consumption as well as a reduction in total demand for red meat and dairy products.

Results

Potential impacts of an outbreak of FMD in the United States on production revenue earned by each sector were calculated (Fig 2 and 3). Price declines ranged from 1% for rice to 27% for live swine. Lower prices led to severe declines in gross revenues for the most susceptible livestock and feed sectors (ie, beef, dairy products, live cattle, pork, live swine, lamb and sheep meat, live lambs and sheep, and forage). Except for poultry and egg producers, price declines were reinforced by reductions in animal and meat output, which resulted in larger revenue declines. For beef, live cattle, pork, and live swine, the relatively larger losses reflected the greater importance of exports to these sectors. Losses for live lambs and sheep, lamb and sheep meat, and milk were dominated by losses attributable to consumer fears. Forage gross revenues declined as a result

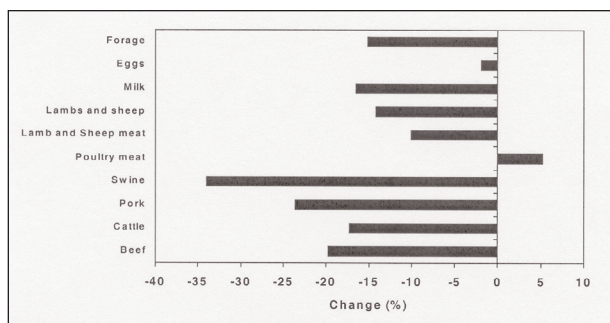


Figure 2—Potential percentage change in livestock-related gross revenues as a result of an outbreak of FMD in the United States.

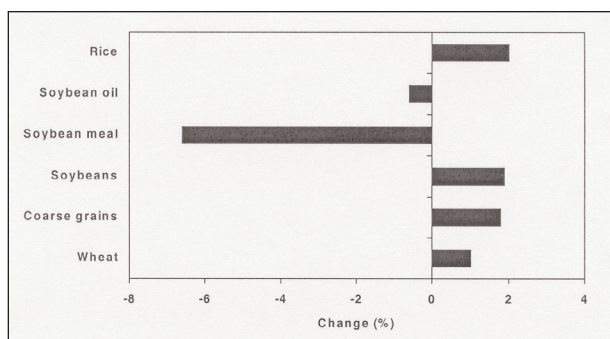


Figure 3—Potential percentage change in gross revenues for grains and oilseed as a result of an outbreak of FMD in the United States. Coarse grains include corn, sorghum, barley, oats, rye, millet, and mixed grains, with corn being the dominant coarse grain in the United States.

of lower prices combined with the decreasing consumption attributable to a smaller livestock population.

Small increases in gross revenue, despite lower prices, for poultry meat, soybeans, coarse grains, and wheat can be attributed to several factors. According to our scenario, consumers shifted consumption away from red meat and toward poultry. This shift, combined with an increase in export of poultry meat, absorbed the increased supply of poultry meat resulting from the lower feed costs. Responses for grains and oilseed sectors reflected the interaction of government support programs and market forces. Market prices decreased as a result of reduced feeding, although this effect was dampened by an increase in exports. With the expansion of poultry and egg outputs, feed usage of soybean meal and coarse grains was reduced less than feed usage of wheat and forages. The reduced forage output decreased rent for land and released some land to production of other crops. Crop prices received by farmers were supported by increased Loan Deficiency Payments; therefore, outputs of grains and soybeans increased slightly.

Percentage changes for each agricultural sector can be translated into dollar amounts and placed in perspective. The decline in livestock supply, an embargo on susceptible US exports, and consumer fears led to a decrease in US export values of \$6.6 billion (decrease of 13%), whereas consumer food expenditures decreased 7%. Government support payments directed primarily to the grains sector increased by \$1.8 billion (increase of 8%). Farm income decreased \$14 billion, which represented 6.2% of US gross cash farm income. Gross cash income includes fruits, vegetables, cotton, and other products not included in the model. Adjusting for the revenues of commodities excluded from the model yielded a loss of 9.5% in gross revenue for the commodities modeled. Of the loss of \$14 billion, \$12.5 billion was in the sectors of cattle, milk, swine, and sheep and lambs, which represented a loss in revenue of 20.4%.

Because the model included vertically linked sectors, and the effects of the FMD outbreak would be transmitted vertically, impacts on gross revenues can be adjusted for changes in input costs along the marketing chain. For example, meat prices were lower but so were animal prices. Animal prices were lower but so were feed costs. Revenue earned by animal slaughter and processing industries, adjusted for lower animal prices, decreased by 15.9% to \$9.1 billion. Revenues in animal agriculture, adjusted for lower feed costs, declined 12.9% to \$43 billion. Returns to crop producers in the model, adjusted for reduced land costs, decreased 7%, which was attributable exclusively to losses incurred for forage production.

Although the magnitudes of each of the 3 components included in our model were unknown, the uncertainty surrounding the magnitudes of the supply reductions and adverse consumer response were greatest. Thus, alternative magnitudes for these components were considered to enable us to evaluate implications for the results. When output losses from the FMD outbreak were reduced by half, there was little impact on the results. Farm income decreased by \$13.6 billion instead of \$14 billion. Results for our model were much more sensitive to the assumed consumer

reaction. In our baseline scenario, we assumed a decrease of 10% in consumption of red meat and dairy products with an increase of 10% in consumption of poultry meat. If a stronger adverse reaction were assumed (decrease of 20% in consumption of red meat and dairy products), the loss in farm income would increase dramatically to \$20.8 billion. Conversely, if consumers did not have an adverse reaction, loss in farm income would only be \$6.8 billion.

Discussion

The study reported here used data from the spring 2001 outbreak of FMD in the United Kingdom to help us estimate the economic effects of a similar outbreak in the United States. One conclusion from the results of our model was that the potential output losses from an FMD outbreak were not the source of the largest impacts. Although FMD-induced removal of livestock would be devastating for individual producers, the impact from the perspective of the aggregate agricultural sector would be small, resulting in a decline in US farm income of < 1%. This should not be surprising, because relative to total animal populations, the proportion of each type of animal removed would be small.

Larger impacts of an FMD outbreak were from the loss of export markets and consumer fears. When the export loss was included, loss of farm revenue for commodities included in the model increased dramatically to 4.6%. Adding an adverse consumer response caused another dramatic increase in the revenue loss to 9.5%. These impacts were the result of a sharp decrease in prices, which magnified producer losses and increased government support payments. Decreases in food prices benefited consumers, but those effects were balanced against a reduction in the quantities of red meat and dairy products that were consumed.

Analysis of these results suggested 2 approaches that could be used by the veterinary medical community to help reduce the impact of an outbreak of FMD in the United States. One approach would be to develop strategies that would enable foreign buyers to regionalize the United States on the basis of the risk posed by the outbreak, thus minimizing the effects on exports of livestock and livestock products. Instilling confidence in foreign buyers that an outbreak would be detected early and contained to a specific region of the United States could allow unaffected regions within the United States to continue exporting livestock and livestock products. The second approach would be to mitigate adverse consumer reactions to an outbreak by raising public awareness that the risk of transmitting FMD to humans through the consumption of red meat and dairy products is negligible. According to the analysis reported here, preventing an adverse consumer reaction would decrease negative impacts on revenue by half.

^aCoarse grains include corn, sorghum, barley, oats, rye, millet, and mixed grains. In the United States, corn is the dominant coarse grain.

^bAs of Nov 27, 2001, the percentage reductions for various livestock in the United Kingdom were as follows: cattle, 5.5%; swine, 2%; lambs and sheep, 10.5%. These results were not sig-

nificantly different from those of May 21, 2001 that were used in our analysis.

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Appendix

Model structure and variables used to determine economic impact of an outbreak of foot-and-mouth disease in the United States

The model structure was based on the primary problem of maximizing the value of national output subject to resource constraints and the secondary problem of minimizing the cost of national resources subject to competitive pricing. Complementarity provides a set of conditions that describe production, factor use, and factor pricing. A general equilibrium formulation with intermediate inputs from another report⁵ was used. A partial-equilibrium version for wheat and wheat flour that is a simple version of this model has been reported elsewhere.⁶

We assumed that goods were produced by perfectly competitive profit-maximizing firms by use of constant returns to scale technologies. Each industry has specific factors of production (ie, Ricardo-Viner model). Firms were considered price takers for inputs purchased from outside agriculture. Goods classified as pure final goods were beef, pork, poultry meat, lamb and sheep meat, milk, eggs, rice, and soybean oil. Goods classified as intermediate and final goods were coarse grains and wheat. Goods classified only as intermediate goods were cattle, swine, poultry, lambs and sheep, soybean meal, forages, and soybeans. Land was considered a primary input.

Final demands were described by a demand system. Demands for intermediate factors of production were determined from the production behavior of each vertically linked industry. For example, beef production determined cattle slaughter; cattle, swine, poultry, milk, and egg production determined the demand for each feedstuff; and crop production determined the demand for land.

Live animals, forages, and land were treated as nontraded inputs. Other commodities were traded according to excess demand and excess supply functions.

The model was solved by differentiating the entire system of equations and converting those equations into logarithmic form. Alterations to the model (expressed as percentage changes) were used to estimate the percentage changes in endogenous variables. These percentage changes were applied to the 1999 database.^{7,8}

Critical variables that determined the percentage changes were the own and cross-price elasticities, unit revenue shares, and substitution elasticities. Price elasticities for commodities as final goods were obtained from several sources. Estimated price elasticities for beef (−0.57), pork (−0.762), and poultry meat (−0.276) were obtained from a study by Eales and Unnevehr.¹¹ Estimated price elasticity of lamb meat (−0.4) was obtained from a study by Paarlberg and Lee.¹² Estimated price elasticity for milk (−0.397) was obtained from a study by Gould et al.¹³ Estimated price elasticities for wheat (−0.309) and rice (−0.328) were obtained from a study by Gao et al.,¹⁴ whereas estimated price elasticity for coarse grains (−0.1) was obtained from a study by Holland and Meekhof.¹⁵ Estimated price elasticity for soybean oil (−0.314) was obtained from a study by Yen and Chern.¹⁶ Estimated price elasticity for eggs (−0.1103) was obtained from a study by Huang.¹⁷

Shares for the cost of individual inputs in the unit revenue (producer price) needed to be indicative of the general cost structure for each industry. Unit revenue shares for beef, pork, and lamb meat were obtained from averages for meat packers reported by the USDA-Grain Inspection, Stockyards and Packers Administration,¹⁸ which indicated that 60% of the price was attributable to the cost of the animal. Specific values for pork were reported by MacDonald and Ollinger,¹⁹ with the animal contribution accounting for 74% of the price. Unit revenue shares for coarse grains (corn) and soybeans were calculated from crop budgets reported by Doster.²⁰ Revenue shares from wheat, rice, milk, beef cattle, and hogs were obtained from the USDA-Economic Research Service.²¹ Current information for lambs and eggs was not found, so we used data reported in 1986.²² For crops, unit revenue included government payments. The unit revenue share for land ranged from 26.5% for rice to 48.8% for soybeans. Purchased inputs also represented large revenue shares that ranged from 37.5% for soybeans to 66.6% for rice. For animals, large unit revenue shares were evident for purchased inputs (20 to 40%) and for feeds. Among feedstuffs, the largest shares in swine, lamb, poultry, and egg production were for coarse grains followed by soybean meal. The largest share of feed costs for beef and milk was forages followed by coarse grains.

Elasticities of substitution values were important parameters but are not widely available. MacDonald and Ollinger¹⁹ estimated values for hog slaughter, and these were used to calculate the required values for all meat sectors. A complete set of own and cross-price elasticities in Dutch compound feeds by feed type was estimated by McKinzie et al.²³ These elasticities were used to calculate elasticities for feed substitutions. Other substitution elasticities were set at −0.3 assuming limited factor substitution possibilities.